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THE CEMENTING PROCESS
OF EXCLUDING WATER FROM OIL WELLS
AS PRACTICED IN CALIFORNIA

BY

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CONTENTS.

	Page.
Introduction	5
Exclusion of water from oil wells	5
Two general methods of cementing oil wells	6
Recommendations and suggestions	6
Pump method of cementing	9
Use of the cement plunger	10
Use of the cement plug	11
Publications on petroleum technology	12

ILLUSTRATION.

	Page.
FIGURE 1.—Baker cement plug	11

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THE CEMENTING PROCESS OF EXCLUDING WATER FROM OIL WELLS, AS PRACTICED IN CALIFORNIA.

By Ralph Arnold and V. R. Garfias.

INTRODUCTION.

This preliminary paper is published by the Bureau of Mines as one of a series dealing with the important problems relating to the technology of petroleum, with especial reference to lessening waste in the exploitation of oil deposits on or adjacent to public lands, and increasing efficiency in the use of fuel oil by the Government. Most of the information has been furnished by oil operators, among whom may be mentioned Messrs. Thomas O'Donnell, W. A. Williams, W. R. Hamilton, R. S. Hazeltine, T. Crumpton, R. C. Baker, J. M. Wells, E. W. Stow, Chester Naramore, and J. M. Robertson. To these gentlemen, and many others, the writers wish to extend their thanks for hearty cooperation, without which this paper could not have been prepared.

EXCLUSION OF WATER FROM OIL WELLS.

One of the most important problems connected with the economical recovery of oil, is that of the permanent exclusion of the water before or after the oil reservoirs are reached. As one of the most experienced operators in California forcibly expresses it, "The oil industry is the most important water business in the State."

In California the exclusion of water has been accomplished in a number of ways, determined by the local conditions, but so far the most uniformly successful method is the cementing process, which is used with slight modifications throughout the 11 principal districts in the State.

Although in some wells cement or cement grout is used between the casings in order to form an impervious packing, which stops the inrush of water, this expedient is employed only in extreme cases, and, as can be readily understood, does not affect the migration of oil or water through the strata penetrated by the wells. To prevent the flooding of the oil sands by the waters above or below, it is necessary to force the cement into the space outside the casing in order to form a water-tight bond between the casing and the walls of the hole.

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The details of the operation vary with the location of the water sands in relation to the oil-bearing beds, it being comparatively easy to "case off" waters occurring a considerable distance away from the oil zone, and proportionately harder to exclude water immediately over, between, or below the oil-bearing sands; and these difficulties are greatly magnified with the increased depth of the wells. The porosity of the formations penetrated, the different gravities of the oils, and the varying gas and hydrostatic pressures affecting the oil or water are also important factors having a direct bearing on the problem of shutting out the water.

The number of water sands penetrated before the oil-producing zone is encountered varies, being usually from one to five. In some fields there exist two or more distinct oil zones, and a water sand sometimes occurs between these oil zones, in which case the cementing operation becomes doubly important, as the greatest care must be exercised in order to effect the recovery of the oil from these different sands without admitting the intervening water. Oil zones situated as those referred to above are found in the Coalinga-Westside field, where it has been impossible to produce simultaneously from the "light" and "heavy" oil sands without encountering considerable trouble with the water lens that in places occurs between them. The general practice at present is to exhaust the upper sands before tapping the deeper ones.

TWO GENERAL METHODS OF CEMENTING OIL WELLS.

Although there are many processes of cementing in use, which differ as to minor details, the operation is in general accomplished in two ways: (1) By pumping the cement mixture through the tubing, whence, unable to flow back between the tubing and the casing, it is forced outside the casing; or (2) by lowering the cement mixture in a dump bailer, and forcing it to the outside either by means of a plunger driven down with the aid of water under pressure, or with a plug fitted to the end of the casing. The first-mentioned method is commonly known as the pump method, and the devices used for the latter, according to detail, are variously designated by the names of inventors, as the Perkins cement plunger, or the Baker cement plug.

RECOMMENDATIONS AND SUGGESTIONS.

Previous to discussing specifically the two processes mentioned above the following recommendations and suggestions are presented. These should be observed, irrespective of the process employed, in order to accomplish a successful cementing operation:

1. A careful study of the well records in all neighboring wells should be made, in order to understand the underground conditions

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of the immediate territory, before it is decided at what depth or in which formation the casing should be "landed" and cementing undertaken.

2. The condition of the hole should be such as to allow the free lowering and raising of the casing, thus assuring between it and the walls of the hole a space through which the cement mixture may move or circulate before the initial setting takes place. It is usually a good plan to underream the lower 30 or 40 feet of the hole, thus facilitating circulation and the formation of a thick protective layer of cement around the lower portion of the casing.

3. The well should be cleaned of all débris and mud, and enough clear water should be pumped in to wash out any sulphur or alkaline water.

4. It should be ascertained whether the casing leaks by the use of a casing tester or other effective means.

5. Previous to cementing, some definite information should be gained relative to the action of the water in the hole on the setting qualities of the cement. If the action is detrimental, a chemical analysis of the water should be made with the intent of ascertaining and perhaps correcting the deleterious effect of the particular salts in solution. An excess of gypsum in the water might delay the setting of ordinary cement three to four months. To meet this condition a quick-setting cement should be used. Considerable quantities of alkali in flowing water may destroy or disintegrate cement.

6. Whatever the composition of the water in the hole, it is of the utmost importance that the water used for mixing with the cement be as pure as possible, preferably condensed water from the boiler, as the character of the water will have a controlling effect on the subsequent behavior of the mixture. If the water is warm the time of setting will probably be shortened. In all cases the mixture should be as thick as can be conveniently handled under the circumstances.

7. As the initial setting of cement under ordinary conditions takes place in about two hours after the mixing with water, this time will to a certain extent limit that employed in the operation, but as the mixture remains comparatively soft for two hours longer, the cement may possibly be pumped during the third or fourth hour after mixing if greater pressure is exerted.

8. Although no appreciable change occurs in the cement after being allowed to set for about two days, the hole preferably should not be disturbed for two weeks, during which time the pressure maintained should be as nearly as possible that used during the cementing. In one well, however, where the ordinary precautions were used, the cement was found to be in a fluid condition and was readily pumped out after remaining in the hole for 13 days.

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9. In shallow wells it may sometimes be advantageous to pump in cement until it reaches the surface, an indication that all the cavities are filled, and that when the cement shall have set, it will form a protective coating around the casing for its full length. Such a procedure is also advisable in any well where the waters are of such character as to corrode the casing quickly.

10. The approximate quantity of cement to be used should be carefully ascertained after a close study of neighboring operations. If the quantity be too small, the result will be unsatisfactory, and if the pumping be done indiscriminately the expense will be increased without improving the chances of accomplishing a successful job.

11. After the cement has been pumped into the hole and the casing lowered to the bottom, all the mixture that remains inside the casing should be bailed out as soon as possible before it sets, as the subsequent drilling of such a cement core is difficult and is responsible for many of the failures in cementing wells, the jar from the heavy tools causing the cement outside the casing to crack.

12. After the cement has been allowed to set a sufficient time, the water should be withdrawn, the operation being gradual in order to avoid the possible collapse of the casing or the jamming of considerable loose material on the bottom from the inrush of the outside water if the cementing operation has not been successful. By pumping the water, say one-third at a time, at intervals of 12 hours, any sudden inflow will be readily noticeable by the rising of the inner water level, and this rising water will tend to equalize the hydrostatic pressures outside, and thus prevent the collapse of the casing. Should the well be a comparatively shallow one, the pressure of the outside water will not be sufficient to cause the failure of the casing, so that it may be advisable to keep the hole bailed dry from the beginning. In order to ascertain whether the water has percolated through holes in the casing itself, a casing tester may be used. This consists of two or three joints of tubing open above and closed at the lower end, and having bolted at the open end a ring of belting of such diameter as to fit snugly into the casing. The tester is lowered with the sand line, say 500 feet at a time, and withdrawn to observe whether any water has collected in the tester throughout that distance, and by repeating the operation it can be ascertained whether the casing leaks, and if so, at what place.

13. In general, most of the failures of the cementing operation can be attributed to improper circulation on the outside of the casing, poor quality of cement, the deleterious effect of salt waters on good cement, lack of sufficient pressure in the pump to overcome unforeseen obstacles, or, where gas has been encountered below the place where cementing is to be undertaken, to the improper exclusion of the gas, a condition that will keep the cement above constantly agitated and prevent it from setting.

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PUMP METHOD OF CEMENTING.

The procedure in connection with the pump method is as follows: After the space between casing and tubing has been filled with water and after the fact that the casing can be lowered and raised without difficulty has been ascertained, the casing is hung 6 to 24 inches above the bottom. A column of tubing, to the lower end of which is attached a reducer or a T joint, is lowered to about 2 feet above the casing shoe and connected to the pump. Enough water is then forced down to indicate whether it will circulate freely between the outer casing and the wall of the hole; the water also serves to remove whatever slush or alkaline water remains in the well. Before pumping stops, the casing is lowered to the bottom to test whether the bond between the casing and the material upon which the shoe rests is water-tight and whether the casing leaks or not. If the casing is sound, the pressure against which the pump is working will immediately increase.

Seven hundred pounds of cement mixed with about 16 barrels of water is sometimes enough for a successful cementing job in wells 900 to 1,200 feet deep, whereas in other wells as much as 25 tons is necessary properly to protect the hole. The mixture is made in a shallow wooden tank and is pumped continuously until all has been used, when the pump is disconnected to allow the inserting of a wooden plug into the tubing. The plug is then driven down by additional pumping. The plug forces the cement ahead until it reaches the reducer at the lower end of the tubing and so drives all the cement to the outside of the casing. The pressure is kept constant while the casing is being lowered to the bottom, after which the pump is disconnected, the tubing pulled out, and whatever mixture remains in the hole is immediately removed with a bailer.[a]

The cement is allowed to remain undisturbed for 12 to 14 days, when the tools are run in and the hole drilled out for about 10 feet below the casing shoe; then the well is allowed to stand undisturbed 15 to 24 hours as a final test.

In some wells drilled by the rotary method, it is advisable to pump the cement into the casing, which has been perforated for some distance above the rotary bit to allow the escape of the cement to the outside. The cement is then poured into the casing and forced down with a wooden plug propelled with the aid of the pump. The water below the cement passes through the perforations to the outside, the cement following. When the upper plug reaches the closed end of the casing all the cement has presumably been driven out.

[a] J. M. Wells, who has been successful in cementing comparatively shallow wells in the Coalinga-Westside field by the above method, informs the writers that as a rule no more than a bailerful of cement is removed after the casing has been landed.

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In the best practice a pump capable of maintaining a pressure of 700 or 800 pounds per square inch is provided for use with the pumping method. Although this pressure is seldom required to force the cement in, the pump is powerful enough to overcome the difficulties that sometimes arise.

USE OF THE CEMENT PLUNGER.

The cement plunger has been found very effective in the cementing of many wells. Among the advantages that can be claimed for it is that no tubing is required in connection with its use. The following description gives an idea of how the plunger is used:

After the fact that the casing is free and the circulation is established has been ascertained, the casing is pulled up about 2 feet from the bottom and about 10 barrels of clear water pumped in to wash out any slush or mineralized water that may have accumulated in the lower portion of the hole. The circulating head is removed and two iron disks, connected by a cast-iron stem about 2 inches in diameter and 3 feet long, are placed in the casing. These disks have a diameter about three-fourths of an inch smaller than that of the casing. A ring of rubber belting attached to the rim of each makes it fit the casing snugly, and keeps the cement from forcing its way past and mixing with the water already in the hole. The mixture is pumped into the casing, forcing the disks down, and after the cement has all been pumped in, the cap on the circulating head is again removed and another iron disk put in, similar to the ones already inserted, except for a cup-shaped leather follower which fits snugly in the casing and is attached to it at the top. The cap on the circulating head is then put in place and water pumped into the well, forcing the whole column of water and cement down until the lower disk reaches the bottom of the hole, leaving the uppermost disk about 1 foot inside the casing. The pressure from the pump forces the cement past the pliable washer attached to the upper disk. The pumping is continued until the upper disk is forced down on top of the one already at the bottom; the leather follower attached to the top of this disk being cup-shaped expands under pressure to the side of the casing, blocking the discharge. The pressure gage on the pump immediately indicates that the cement is all out of the casing. Double assurance that the cement has all been displaced by the water may be had by measuring the water pumped into the hole after the cement. The bailer should be used in a couple of days to remove any cement that may have slipped past the disks at the inside of the casing. The disks being of cast iron, are easily drilled out afterwards. The time required in this process for the cementing operation proper is only about 1 hour.

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USE OF THE CEMENT PLUG.

The cement plug is shown in figure 1. When this device is to be used in connection with cementing a well, the cement mixture is either conveyed to the bottom of the "open" hole by a dump bailer or, if the formation is apt to cave, the mixture is dumped in while the casing rests on the bottom and the casing is subsequently pulled out of the cement.

After it has been determined that there is no cement in the casing, the cement plug is hung by a soft rope from a bailer. As the bailer is lowered down the hole, the slips (*a*, fig. 1) on the plug slide upward, thus allowing the plug free passage. When the plug strikes the water the weight of the bailer on the valve stem causes the valve *b* at the bottom of the plug to open thus allowing the water to pass through and the plug to descend freely. When the plug passes out of the casing the slips drop, and if a slight tension is exerted on the sand line the plug is brought against the casing shoe and the slips catch thereon, closing the valve and furnishing the casing with a closed pointed end that effectually prevents the passage of any material back into the casing. The casing is then lowered into the cement with enough strain on the bailer to hold the plug tight against the shoe, but not enough to break the soft rope between the bailer and the plug. Care must be exercised in this operation to see that the bailer is lowered with the casing, otherwise the tie between the bailer and the plug may break and the plug fall into the open hole.

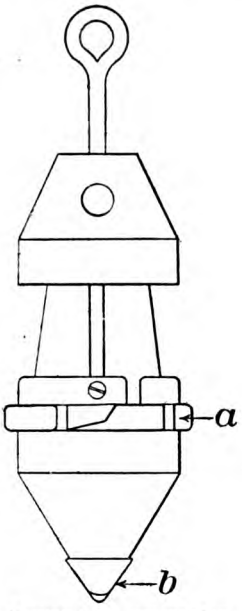

FIGURE 1.—A cement plug. *a*, Slips; *b*, valve.

As soon as the casing has been set into the cement and will go no farther, the bailer is jerked loose from the plug and pulled out; then, if the weight of the casing is not sufficient to cause it to settle through the cement to the bottom of the hole, the casing may be driven down. The valve in the plug being closed and the slips fitting tight in the shoe none of the cement can go back into the casing, and it will therefore be forced into the formation or up the hole on the outside of the casing. The plug, being made of cast iron one-half inch thick, can be easily drilled out.

One of the advantages of the method of lowering the cement to the bottom of the casing before forcing it out is that the cement can be mixed thicker than under the pump methods; consequently a smaller

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quantity is needed. In many cases it is advisable to cement and test certain formations before going deeper. Under this method, as not so much cement is used, the subsequent loosening of the casing would probably be easier should removal be desirable.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

The following publications may be obtained free of cost by applying to the Director, Bureau of Mines, Washington, D. C.:

BULLETIN 19. Physical and chemical properties of the petroleums of the San Joaquin Valley of California, by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the oil fields of southern California, by G. A. Burrell. 1911. 360 pp., 2 pls.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 10. Liquefied products from natural gas; their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1911. 11 pp.

TECHNICAL PAPER 26. Methods of determining the sulphur content of fuels, especially petroleum products, by I. C. Allen and I. W. Robertson. 1911. 13 pp.

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